

# THESEUS science requirements

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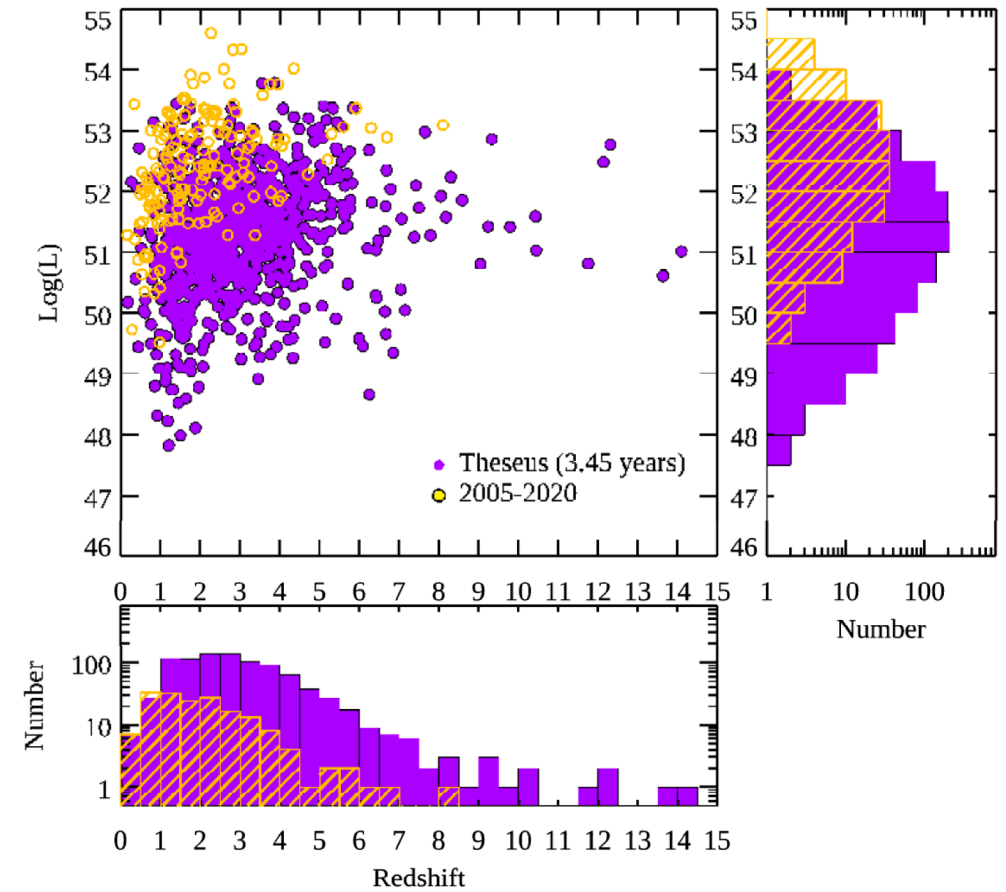
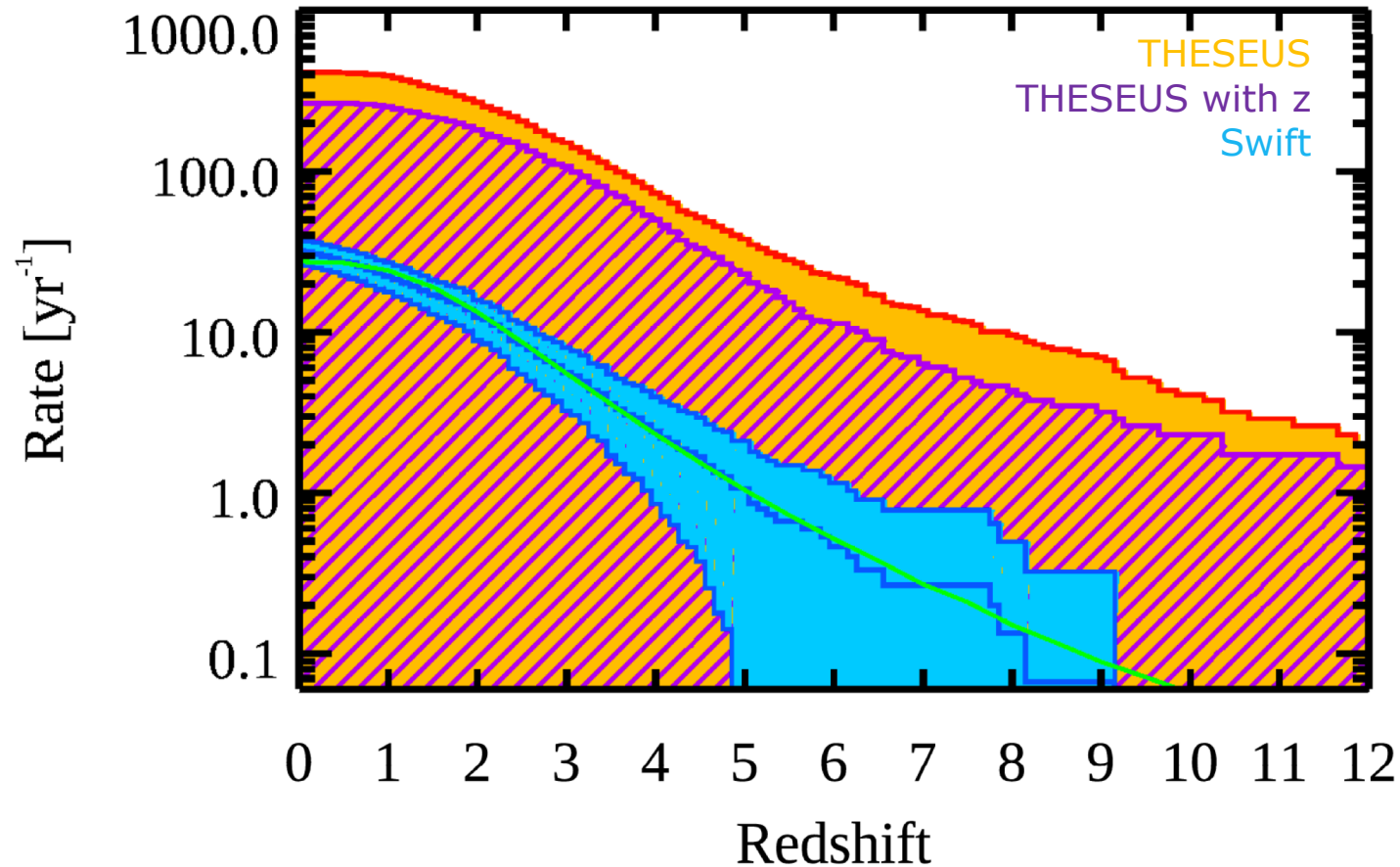
on behalf of the THESEUS Science Study Team

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# THESEUS is a wonderful mission, but ...

## Expected distributions of long GRBs: THESEUS vs. now



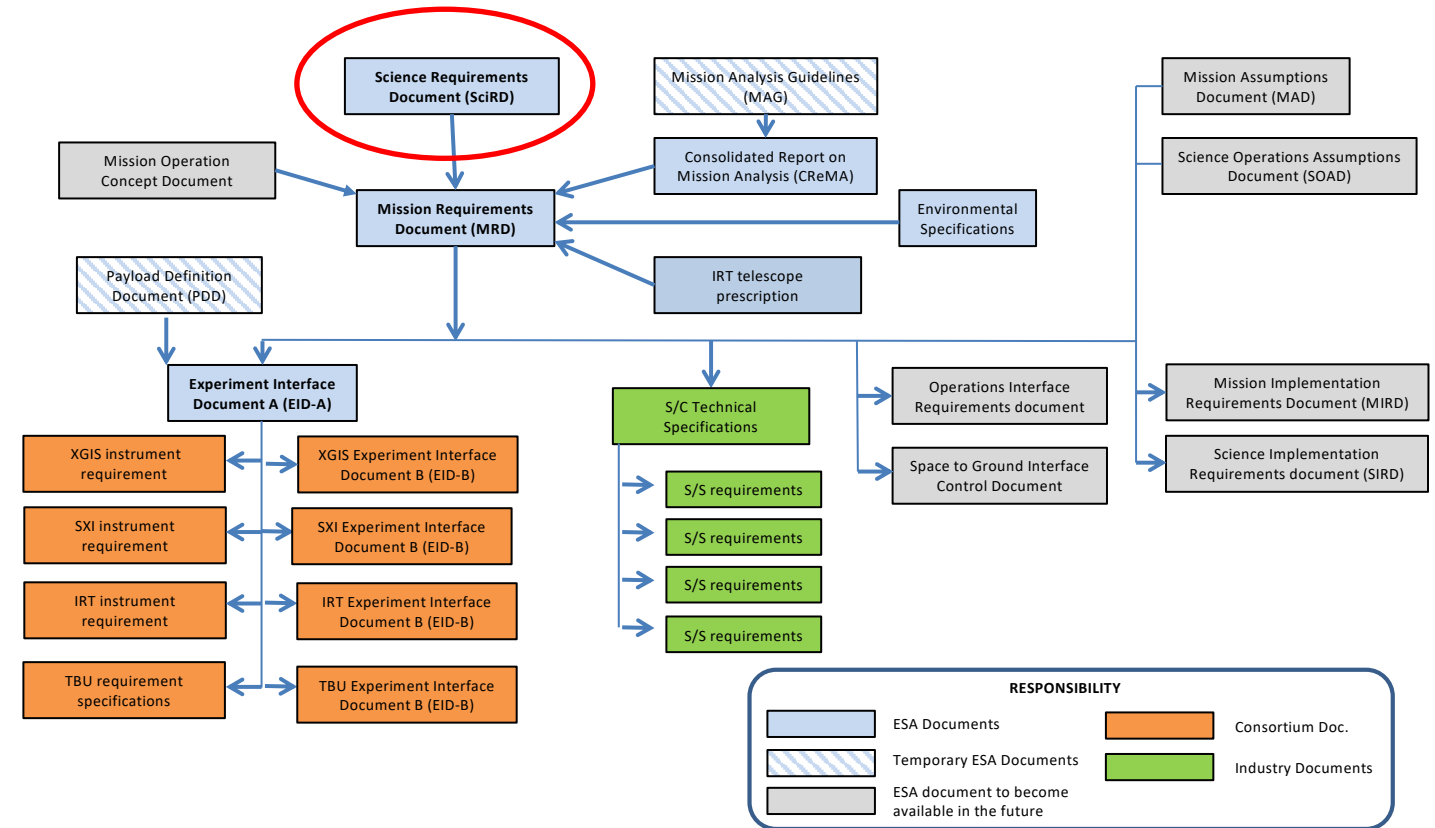
Credit: Giancarlo Ghirlanda (OAB)

Figure extracted from the THESEUS "Yellow Book": [https://sci.esa.int/documents/34375/36249/Theseus\\_YB\\_final.pdf](https://sci.esa.int/documents/34375/36249/Theseus_YB_final.pdf)

# ... we need an engineering demonstration

Credit: ESA THESEUS Study Team

THESEUS Phase A Requirement Documents (2019-2021)

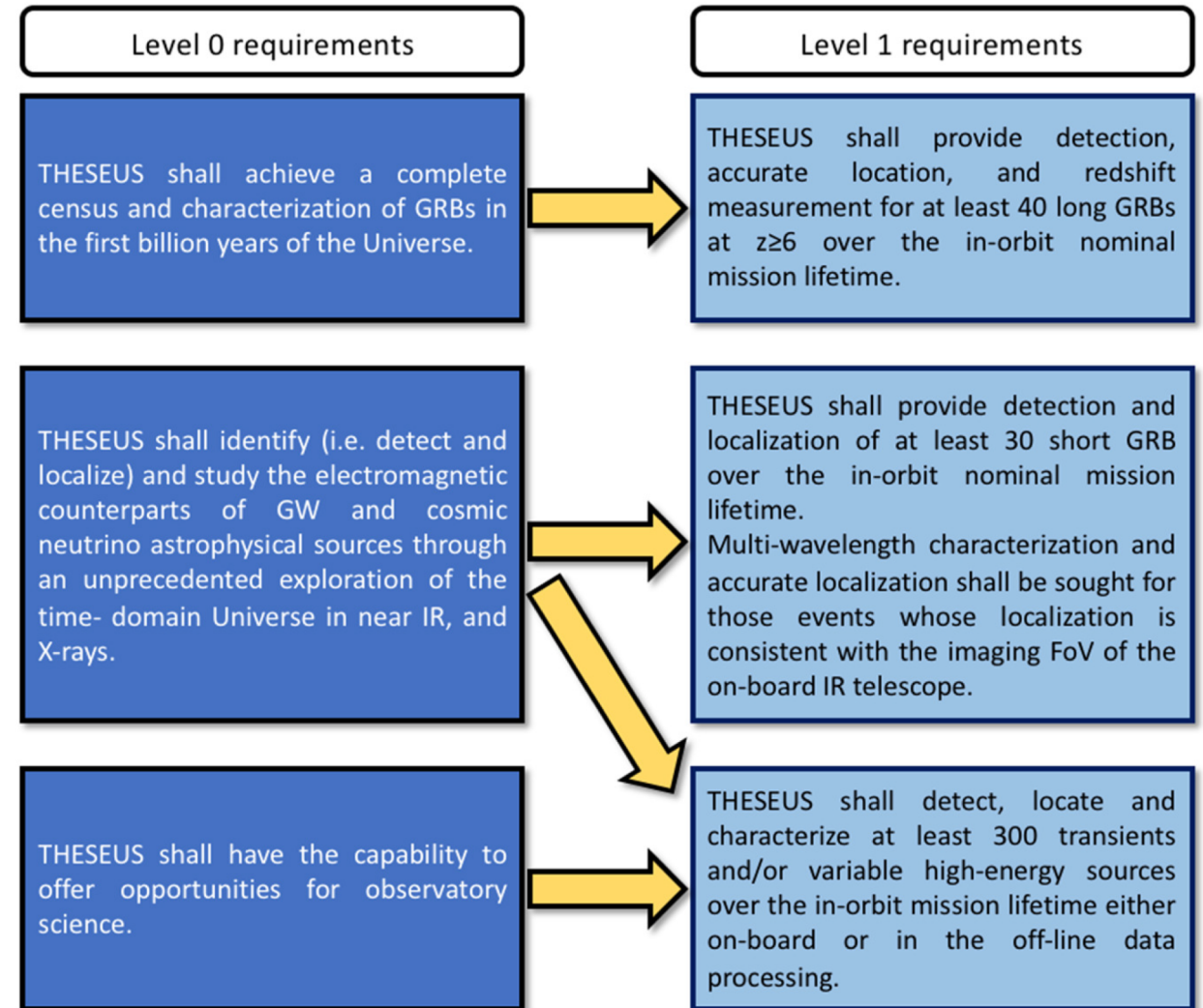


- The **Science Requirement Document** is at the top of the document structure of an ESA Study
- Formal deliverable of the **THESEUS Science Study Team**
  - ESA document, but with direct inputs from the whole science community
- Requirements level
  - L-0: overarching **science goals**
  - L-1: implementation-**independent** requirements
  - L-2: implementation-**dependent** requirements (e.g., payload performance)
  - L-3: mission specifications (not in the SciRD)



# Top-level science requirements of THESEUS

- **“Beacon” cosmology**
  - Complete census of long GRBs in the first billion year of the Universe
- **Multi-messenger astrophysics**
  - Identification and (multi- $\lambda$ ) study of electromagnetic counterparts of GW and  $\nu$  events
- **The X-ray transient Universe**
  - Unprecedented survey of the IR/high-energy Universe
  - Opportunity for observatory science



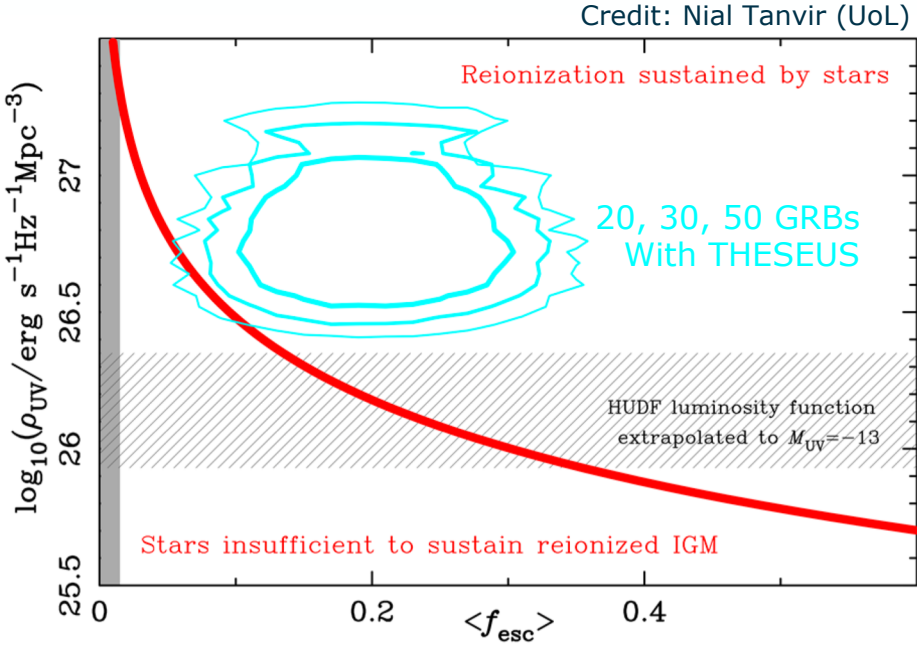


# Level-1 key requirement #1



THS-SCI-R-101	Number of long GRB (very high-redshift)			
Definition	THESEUS shall provide detection, accurate location, and redshift measurement for at least 40 GRBs at $z \geq 6$ (corresponding to approximately the first billion years of the Universe in the standard $\Lambda$ CDM cosmology) over the in-orbit nominal mission lifetime.			
Synopsis	Value	Units	Condition or Instrument	Parent Requirements
	$\geq 40$	-		THS-SCI-R-010

- Unveil and characterize the population of low-luminosity primordial galaxies
- Assess global star formation history of the Universe up to  $z \sim 10$
- Shedding light on re-ionization sources
- Investigate the InterStellar (ISM) and InterGalactic Medium (IGM)
- Unveil observational constraints on first stars (PopII/III)



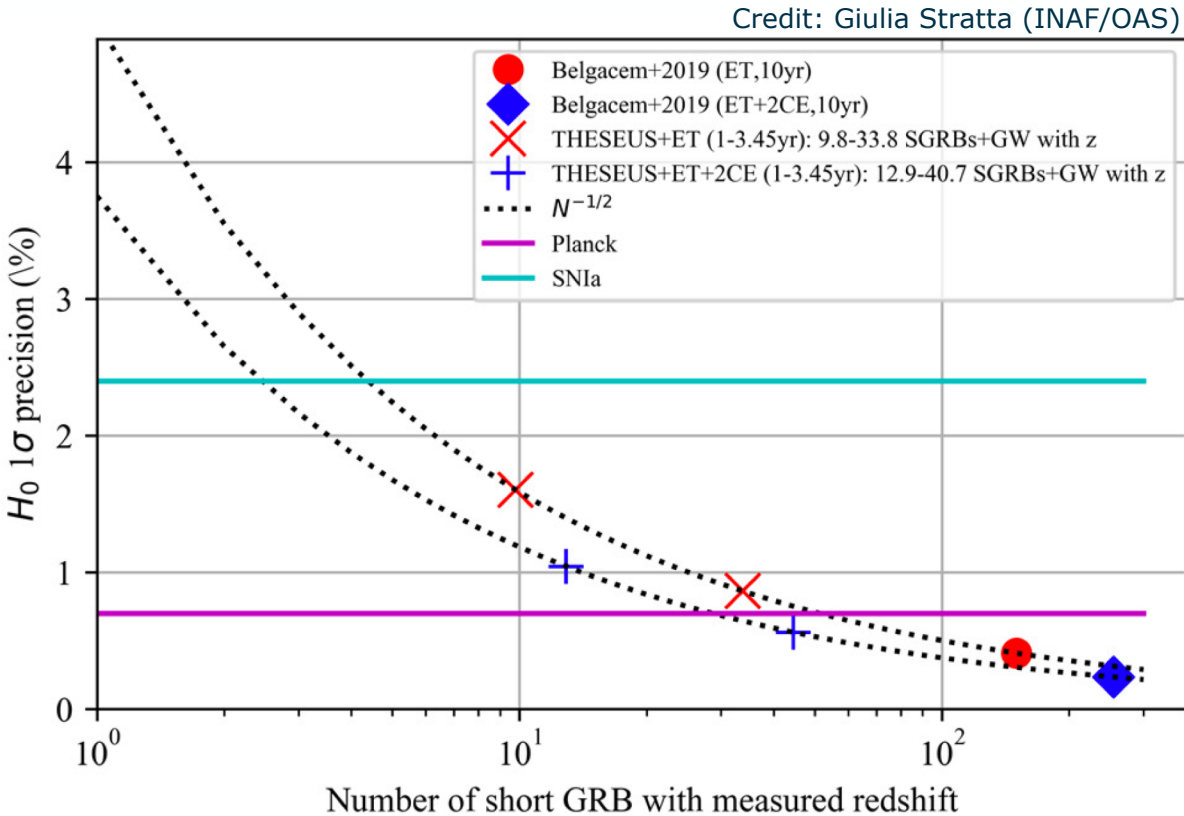
# Level 1 key requirement #2 and #3



THS-SCI-R-103	Number of short GRB			
Definition	THESEUS shall provide detection and localization of at least 30 short GRB over the in-orbit nominal mission lifetime. Multi-wavelength characterization and accurate localization shall be sought for those events whose localization is consistent with the imaging FoV of the on-board IR telescope.			
Synopsis	Value	Units	Condition or Instrument	Parent Requirements
	≥30			THS-SCI-R-020

THS-SCI-R-110	Number of transients and/or variable X-ray sources			
Definition	THESEUS shall detect, locate and characterize at least 300 transients and/or variable high-energy sources over the in-orbit mission lifetime either on-board or in the off-line data processing.			
Synopsis	Value	Units	Condition	Parent Requirements
	≥300		-	THS-SCI-R-020 THS-SCI-R-030

- Locate and identify EM counterparts of GW and v sources
- Provide triggers and accurate position of transients for follow-up with radio to X-ray observatories
- Deepen our understanding of physics and progenitors of GRBs, and various classes of Galactic and extra-Galactic transients (TDEs, SGRs, SNe, XRBs, AGN, etc.)



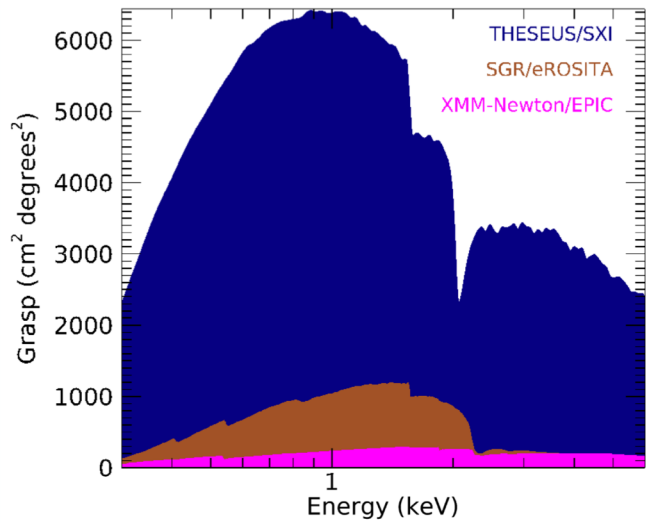
# Level-2 requirements synopsis – I.

## Key mission performance:

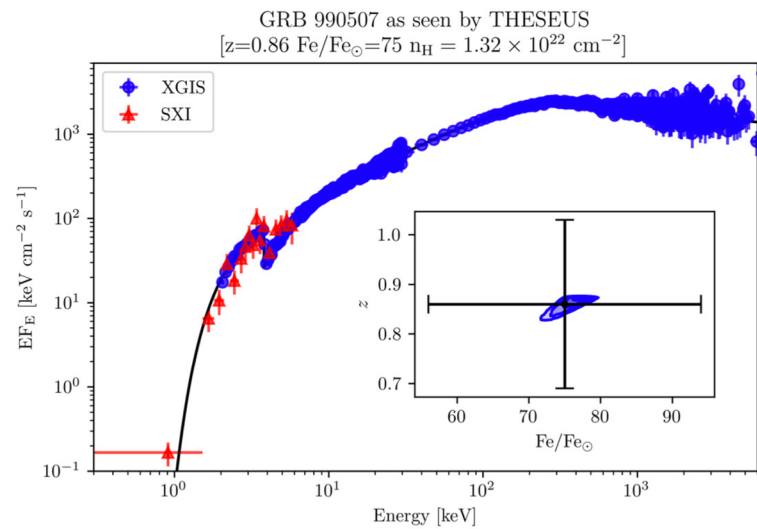
- High-energy grasp (SXI/XGIS)
- Spacecraft autonomy and agility
- On-board redshift (IRT) (photometric and spectroscopic)
- $\sim'/\sim''$  (monitors/IRT) positional accuracy

SXI sensitivity ( $3\sigma$ )	$1.8 \times 10^{-11}$ erg/cm <sup>2</sup> /s (0.3-5 keV, 1500 s) $10^{-10}$ erg/cm <sup>2</sup> /s (0.3-5 keV, 100 s)
XGIS sensitivity (1s, $3\sigma$ )	$10^{-8}$ erg/cm <sup>2</sup> /s (2-30 keV) $3 \times 10^{-8}$ erg/cm <sup>2</sup> /s (30-150 keV) $2.7 \times 10^{-7}$ erg/cm <sup>2</sup> /s (150 keV-1 MeV)
IRT sensitivity (imaging, SNR=5, 150 s)	20.9 (I), 20.7 (Z), 20.4 (Y), 20.7 (J), 20.8 (H)
SXI field-of-view	0.5 sr - 31x61 degrees <sup>2</sup>
XGIS field-of-view (area corresponding to >20% efficiency)	2 sr (2-150 keV) – 117x77 degrees <sup>2</sup> 4 sr ( $\geq 150$ keV)
IRT field-of-view	15' x 15'
Redshift accuracy ( $6 \leq z \leq 10$ )	$\leq 10\%$
IRT resolving power	$\geq 400$
XGIS background stability	$\leq 10\%$ (over 10 minutes)
Field-of-Regard	$\geq 50\%$ of the sky
Trigger broadcasting delay to ground-based networks	$\leq 30$ seconds (65% of alerts) $\leq 20$ minutes (95% of alerts)
SXI positional accuracy (0.3-5 keV, 99% c.l.)	$\leq 2$ arcminutes
XGIS positional accuracy (2-150 keV, 90% c.l.)	$\leq 7$ arcminutes (50% of the triggered sGRB) $\leq 15$ arcminutes (90% of the triggered sGRB)
IRT positional accuracy ( $5\sigma$ detections)	$\leq 5$ arcsecond (real-time) $\leq 1$ arcsecond (post-processing)



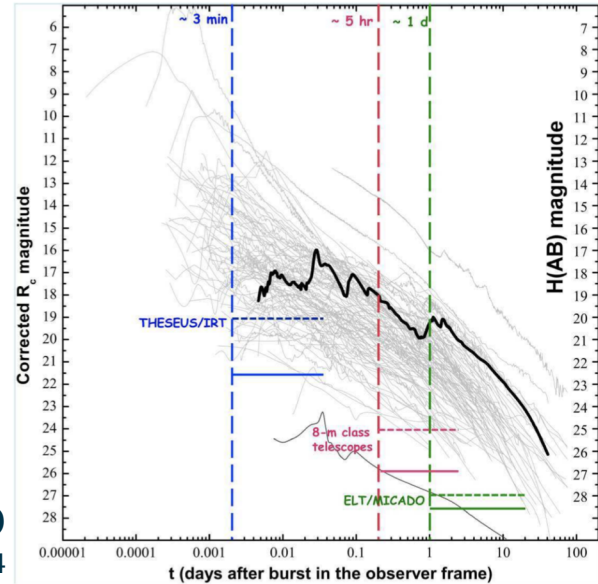


Grasp



High-energy spectroscopy

Credit: Giancarlo Ghirlanda (OAB)

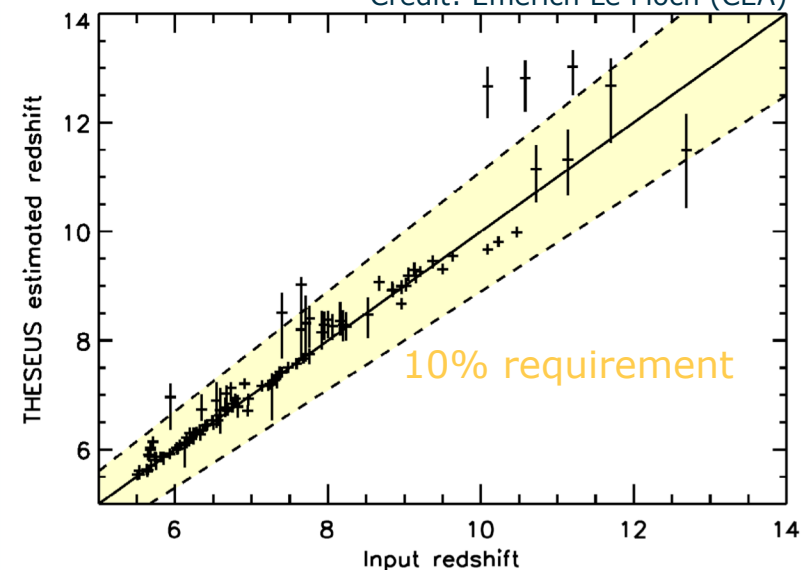


IR follow-up

Rossi et al., 2018, Mam.S.A.It., 89, 254

On-board redshift accuracy

Credit: Emerich Le Floch (CEA)



# THESEUS is the quintessential M5 mission



- THESEUS has successfully overcome all the Six Labors, as ΘΗΣΕΥΣ did:
  - THESEUS smashed our competitors in the **Proposal Phase**, as ΘΗΣΕΥΣ did by grabbing the stout staff of Periphetes (the Club Bearer)
  - THESEUS survived the Underworld of the **Concurrent Design Facility**, as ΘΗΣΕΥΣ did by capturing the robber Sinis
  - THESEUS feasted after the **Mission Consolidation Review**, as ΘΗΣΕΥΣ did after killing the Crommyonian Sow
  - THESEUS will push all uncertainties on the mission design down the cliff of the **Mission Selection Review**, as ΘΗΣΕΥΣ did with the robber Sciron
  - THESEUS will wrestle all the insidious questions by the SARP, as ΘΗΣΕΥΣ did with Cercyon
  - We have survived yet another “*I have a few introductory slides*” by the Lead Scientist, as ΘΗΣΕΥΣ did with Procrustes
- THESEUS is the hero-founder of key *Athena* science cases (e.g.: high-*z* GRB X-ray spectroscopy)
- THESEUS science survived Phase A unscathed, making the “Ship of ΘΗΣΕΥΣ” paradox not applicable